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Healthy Assessment Research Electronic Equipment Based on Data Fusion

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Abstract

Healthy assessment weights of using of modern electronic equipment is too subjective problem, it is proposed in this paper that is based on fuzzy analytic hierarchy process and the method based on the theory of the D-S evidence. In solid state transmitter, for example, by analysis of working principle, from the perspective of healthy status evaluation, it will be associated with healthy status indicators stratified processing. Then according to the hierarchy correlation index from the bottom of each layer in systems integration, the paper consider the complexity of system structure and index measurability, and use the analytic hierarchy process and the D-S evidence fusion solid state transmitter overall healthy assessment results.

Keywords*: Electronic equipment, healthy assessment, analytic hierarchy process, D-S evidence theory*

1. Introduction

With the development of monitoring technology, the theory of healthy monitoring is from condition monitoring to healthy management, the Prognostics and Healthy Management (PHM), the flight Integrated Vehicle Healthy Management(IVHM), Boeing company Aircraft Healthy Management (AHM) and Health use and Monitoring System (HUMS) and other concepts. In addition, the United States department of defense on the basis of the situation and maintenance in recent years, puts forward the concept of enhanced Condition Based Maintenance (CBM+), further consolidated the CBM, and maintenance of reliability management, automatic protection. The goal is to equip the system ability of healthy management and equipment condition monitoring, maintenance decision, after put into use life prediction, logistics, cost control, etc., for the integration of the overall planning and design.

Healthy status assessment of electronic equipment is through the accurate evaluation of equipment Healthy status, which provides the basis for equipment maintenance decision, and provides technical support for the accurate maintenance. In terms of equipment healthy management, healthy assessment is the important basis of the implementation of Healthy management. The validity of the electronic equipment for healthy assessment, based on maintenance decision can improve the availability of equipment, combat readiness integrity, and reduce the use of equipment guarantee fee. Healthy state assessment of the electronic equipment is a multistage complex activities, gradually implement. Complex electronic equipment is a complex system with uncertainty and information, to solve the problem from the uncertain information generated by the random and fuzzy data. Many intelligent evaluation methods are applied to equipment healthy. Such as model method, fuzzy evaluation method,

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Bayesian Network, Analytic Hierarchy Process, and Gray Evaluation Method and Artificial Neural Network, *etc*.

Among of the electronic equipment, the radar system composition is highly complex, and frequent using and failure rate is high. The radar transmitter is in the most typical. The radar transmitter is as the research object for three reasons.

(1) Radar transmitter structure is highly complex, which a typically electromechanical mixing equipment with typical structure;

(2) Using frequency of radar transmitter is high, with large power, large current, high voltage, large heat loss of using environmental characteristics, which works in pulse way, low reliability. It is difficult to guarantee and maintenance.

(3) Radar transmitter in radar plays the core functions of RF signal power levels, which the healthy management is of great significance.

Therefore, radar transmitter is chosen as the research object, discuss the key of PHM technology - healthy parameters processing, condition monitoring, healthy status evaluation, healthy trend prediction in radar launch on the custom transformation has important theoretical guiding significance and practical value.

In order to realize the accurate characterization of the equipment healthy status, need to collect running state characteristics of the electronic equipment. In general, the performance characteristic of healthy way is through the arrangement of internal sensor or the equipment of signal sampling circuit for the healthy parameters. Within the current radar transmitting pattern in test system has done more perfect.

Healthy screening of state parameter should be in accordance with the following criteria.

(1) Clarity. Healthy performance parameters of the equipment should be a series of clear representation set the parameters of the equipment healthy status, healthy performance parameter should be accurate, definition of parameters and the correlation between should change with the state of the equipment and show a definite change trend.

(2) Completeness. Numerous factors that affect the healthy status of equipment, healthy status parameter set should be complete enough to complete description of equipment state space, at the same time healthy status parameters should also meet the demand of healthy trend prediction and fault diagnosis of equipment.

(3) Testability. PHM technology requires complete machine test system support. Therefore, select the healthy status of parameters should be arranged in the transmitter for sensor or acquisition circuit. In order to realize remote real-time monitor of the healthy status of equipment, healthy status parameters should also meet the requirements of real-time acquisition, upload, parsing.

The healthy status of equipment parameters is with different format, characteristics and sampling period. The heterogeneity parameters in the parameter contains the amount of information has the difference, at the same time increased the difficulty of the construction of a comprehensive evaluation model of healthy. Heterogeneous data fusion method with expert evaluation method, mathematical operations research method, multi-objective decision method, data envelopment analysis and grey management analysis, etc. The expert evaluation method with too many subjective elements, unable to overcome the problem of lack of comprehensive and logical, integrity requirements of the state space description and other methods are hard to achieve in a short time. Based on healthy status parameters monitoring purpose, establish a unified measure of healthy status parameter normalization method is the best way to solve this problem under the condition of existing. It introduced a certain type of radar transmitter healthy status evaluation process.

2. Parameters Selection and Normalized for Healthy Status of Radar Transmitter

The function of radar transmitter is under the excitation of timing signal and produce high power RF signal. Traditional radar transmitter healthy management mode through arrangement in the data acquisition system of radar transmitter acquisition parameters, and submit to control protection system processing, unified to realize condition monitoring and fault isolation of the radar transmitter. This model has certain test scope, but also exist fault symptom parameters, test data by using single purpose and the problem of insufficient. This paper on the structure and working process of radar transmitter is analyzed on the basis of selecting the transmitter can be characterized of a complete set of healthy status of electronic, electrical, mechanical, thermal parameters, and according to the international standard of data format, the normalized data types. Radar transmitter is a typical radio frequency power generating equipment, because of semiconductor power devices and power synthesis technology mature promoted the high reliability, good shock resistance of the solid state transmitter share rises year by year.

Table 1. Healthy Parameter Data

Indicators	scope of work	threshold
Average power	± 10%	± 15%
Pulse envelope	no	no
Pulse width	0-100%	102%
Transmission power	80%-100%	80%
Power supply voltage	± 10%	± 15%
Instantaneous bandwidth	0-100%	Reduce3%
Water temperature	0-Max	Max
Waveguide pressure	80%-100%	80%
Waveguide lighter	no	yes
Traffic	80%-100%	70%
Standing wave ratio	0-2	2
Machine efficiency	85%-100%	85%

The working process of the pulse compression system of radar transmitter is that RF after amplification by the power synthesis device synthesis of RF signal, and through a standing wave detection, pulse width and output power detection and feedback system than monitoring running day on the job. Because of radar transmitter power amplification circuit and power synthesis, distribution circuit inevitably produces heat loss, in order to avoid overheating temperature affect electronic during work, the cooling system of related circuit for cooling. Cooling system generally USES the cold plate cooling circulation cooling way of related circuit: using hollow pipes clingy circuit, and the cold plate cooling fluid filling cycle. When the surface system is failure, forced air cooling system is to cool the system. In radar transmitter boot or work process, control parameter collection sensor or circuit protection system as a whole control healthy parameters monitoring and collection of transmitter, and in some part of the abnormal failure triggered related action, in order to avoid failure spread or enable backup for tactical tasks, such as when the standing wave ratio is too large to truncate the input signal directly, or in a switching power supply fault enabled when the power of the backup. Comprehensive the above consideration, select the

healthy status of radar transmitter parameters set as shown in Table 1, some parameters are given scope of work and threshold.

Machine testing system of radar on healthy state parameter acquisition, through the corresponding communication mechanism will be uploaded to the data collected healthy management system. The original test data must pass parameters preprocessing mechanism may be the subsequent modules. This paper will be divided into five types according to the format parameter, on the basis of the standard for data preprocessing methods, not only can effectively use the research results of the standard, also for the subsequent heterogeneous parameters normalized brought convenient.

(1) Scalar value data, which is relatively simple data format, generally composed of one or a few data of single value. The scalar value data usually is the direct reaction of state parameter, which also does not need to deal with. Feature extraction can be use directly or just by simply deviation correction and eliminate bulky error, used.

(2) Numeric data, which is simplified form of waveform data or data sequence, for the most part is associated with or related qualitative data collection of scalar value.

(3) Large binary form, which is varied, such as radar signature, cold plate temperature field distribution of the image, as well as electromagnetic signals or acoustic file, such as support for these parameters processing needs corresponding identification technology.

(4) Data sequence, which is a series of sequences with logical order parameter, the common data sequence is time series. Data sequence are handled generally extracted data sequence of relevant features, and the correlation analysis between certain features or characteristics.

(5) Waveform parameters, which in radar transmitter is a kind of typical data forms, pulse modulation signal and linear frequency modulation signal, the parameters such as power supply ripple. Waveform parameters generally with stochastic noise, before using shall conduct to deal with the noise, then extract the data features and the characteristics of evaluation.

The healthy status of radar transmitter evaluation technique is the work state of radar transmitter to assess the status of the deviation from expected. This paper adopts the method of data normalized. The unity of the five types of healthy status parameters is based on the degree of degradation measurement scheme, and set up evaluation index system of the healthy status of the radar transmitter. Also on the traditional fuzzy Analytic Hierarchy Process is improved, reference index scale alternatives to traditional linear scale, simplifies the construction of fuzzy consistent matrix method, and put forward by introducing the factor of changes in weight method based on the degradation degree gives AHP with time-varying characteristics, to make it better able to play a role dynamic comprehensive evaluation.

For example, the solid state transmitter is in healthy assessment work. Through the analysis of principle of solid state transmitter, the perspective of healthy status evaluation will be related to healthy status indicators stratified processing, and then according to the hierarchy correlation index from the bottom of each layer in systems integration, and get the comprehensive evaluation of performance. By considering the complexity of system structure and index measurability, it is using rough set theory for healthy assessment index hierarchy, as shown. Hierarchical structure is divided into three layers, the first layer as the goal layer, is the healthy status of solid state transmitter, the second is the ability to layer. Healthy assessment index of the factors, the third layer is the index layer, solid state transmitter of basal healthy indicators of evaluation. All the indicators for the same healthy performance characterization of indicators-healthy index (HI), normalized all the parameters of the healthy to (0, 1) interval, and then using the analytic hierarchy process. And D-S evidence fusion is to get solid state transmitter overall healthy assessment results.

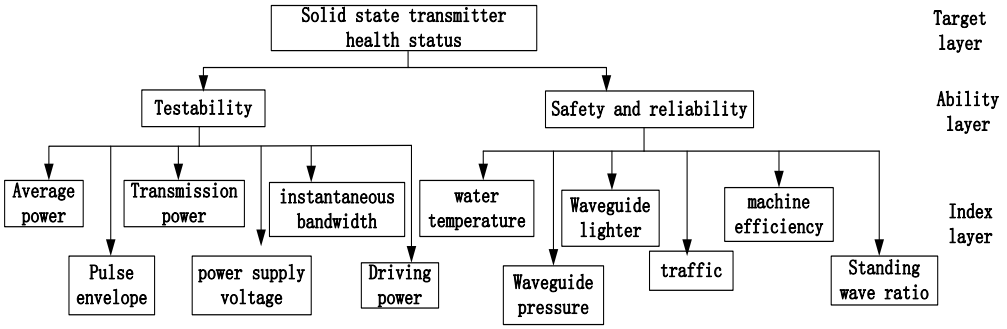

Figure 1. Healthy Hierarchical Maps of Solid State transmitter

3. Healthy Assessment Model Based on D-S theory

3.1. Synthesis Principle Based on D-S theory

D-S evidence theory is based on the Bayesian Networks is a kind of numerical method of uncertainty reasoning. It has established the general Bayesian theory, according to the reasoning model, using evidence to determine the probability distribution and uncertainty multiple under the assumption of the likelihood function. The uncertainty evidence theory is to use the "Half Add" principle, so can be well in the main problems of uncertainty reasoning to compromise, the contradiction between the objectivity.

For as a proposition A, there is A which belongs to Θ . $m(A)$ is referred to as the basic probability. For the same recognition Θ , N independent sources of evidence is export to the credibility of the function $m_1, m_2, ..., m_n$ .The basic reliability by using D-S evidence rules:

$$m(A) = \frac{\sum_{\cap A_i = A} \prod_{i=1}^{n} m_i(A_i)}{1 - \sum_{\cap A_i = \Phi} \prod_{i=1}^{n} m_i(A_i)} = \frac{\sum_{\cap A_i = A} \prod_{i=1}^{n} m_i(A_i)}{\sum_{\cap A_i \neq \Phi} \prod_{i=1}^{n} m_i(A_i)} \quad (1)$$

When the importance of each source of evidence, validity or not at the same time, the confidence level of D-S rules provide the results may be different with the actual situation. Therefore it needs to divide factors to important degree, which will focus on various factors weights of the biggest factors as key factor, other factors as non-critical factors. Through the normalized processing of non-critical factors to reduce the conflict between evidence, and improve the credibility of evaluation results.

3.2. Multi-index Evaluation Model Based on D-S Evidence Fusion

The healthy status of transmitter, the safety and reliability of the transmitter factors such as complicated corresponding relationship. This relationship has a strong fuzzy features and characteristic, evidence space of each index can be used as the evaluation factors set, and the corresponding experts given by each sensor or the corresponding fuzzy membership degree, and then through membership function into characterization of each index evaluation of state basic probability distribution, then by D-S theory of evidence rules of synthetic evaluation index for fusion. As shown in Figure 2.

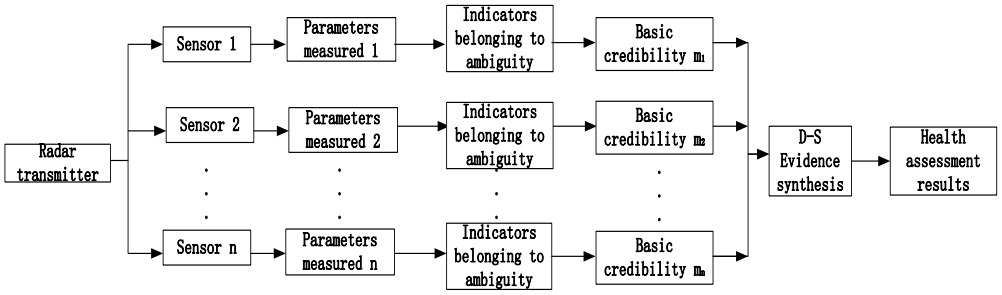

Figure 2. D-S evidence Fusion Scheme of Solid State Transmitter Healthy Assessment

Usually, by l pattern $A_1, A_2, \ldots A_l$, in the domain U , According to the radar sensors or expert experience n membership degree is given $\mu_1, \mu_2, \ldots \mu_n$. The framework of the membership degree of all sensors for identifying is as follows.

$$\begin{bmatrix} \mu_1(A_1) & \mu_1(A_2) & \cdots & \mu_1(A_l) \\ \mu_2(A_1) & \mu_2(A_2) & \cdots & \mu_2(A_l) \\ \cdots & \cdots & \cdots & \cdots \\ \mu_n(A_1) & \mu_n(A_2) & \cdots & \mu_n(A_l) \end{bmatrix}$$

Belongs to the proposition of the basic reliability distribution has get that.

$$m_i(A_j) = \frac{\mu_i(A_j)}{\sum_{j=1}^{l} \mu_i(A_j)} \qquad (2)$$

To get the $m_i(A_j)$, which is constructed by the field of membership function according to experts or sensors, the reserve uncertainty based on the results of observation, avoid the distortion problem of human information processing. Thus it effectively solved the evidence theory in the basic reliability allocation problem.

Basic steps are as follows.

(1) It takes the healthy assessment indicators for evaluating factors set. In fuzzy evaluation set V as an identified frame, $\upsilon_L (\mathrm{L} = 1, 2, 3, 4, 5)$ is to evaluate the specific evaluation. According to expert opinion, it can assume evaluation value that is $P(V) = \{P(v_1), P(v_2), P(v_3), P(v_4), P(v_5)\} = \{0.9\ 0.7\ 0.5\ 0.3\ 0.1\}$.

(2) Determine the credibility of the indexes and weights. Using D-S evidence theory to the indexes of evaluation index system to make a comprehensive evaluation, according to the experts give the membership function of analysis of each evaluation index, to determine the basic reliability index layer. Analytic Hierarchy Process is used to determine the index weights.

(3) To set up the evidence synthesis. To distribute the weight of an indexed standardization and the basic reliability shall be carried out in accordance with the formula of evidence synthesis.

(4) The computing evaluation results is based on $E = \sum_{r=1}^{5} P(\upsilon_r) P(\upsilon_r)$.

(5) Comparing the difference between the assessment results and empirical knowledge to modify the weight, improve the evaluation model.

4. Healthy Assessment for State of Solid State Transmitter

During the period of maintenance, plant team to follow master for repair work, measured data and calculate the relative value shown in the following Table 2.

Table 2. Measuring Data of Solid State Transmitter

Indicators	deviation	Value range	Healthy index
Average power	1.3%	± 10%	0.93
Pulse envelope	1%	± 15%	0.90
pulse width	0.8%	0-2%	0.72
Transmission power	10%	15%	0.70
power supply voltage	0	10%	1
instantaneous bandwidth	1%	3%	0.95
water temperature	0	20%	1
Waveguide pressure	70%	-20%	0.16
Waveguide lighter	yes	No	0.25
traffic	5%	± 15%	0.96
Standing wave ratio	85%	0-2	0.14
machine efficiency	-3.9%	-10%	0.71

Fault conditions of assessment indexes evaluation is divided into five grades. $V = \{v_1$ (There are fault impact on the healthy status mild) , v_2 (There are fault defective transmitter condition is quite good) , v_3 (Fault impact on the transmitter healthy in general) , v_4 (Defective more serious effect on healthy status) , v_5 (Defective serious effect on healthy status) $\}$ .According to expert opinions, can assume evaluation value is $P(V) = \{P(v_1), P(v_2), P(v_3), P(v_4), P(v_5)\} = \{0.9\ 0.7\ 0.5\ 0.3\ 0.1\}$. Using Analytic Hierarchy Process to get the index weight is $W_1 = \{0.316, 0.325, 0.307, 0.022, .0.010, 0.020\}, CR = 0.036.$ $W_2 = \{0.079, 0.175, 0.125, 0.076, 0.099, 0.446\}, CR = 0.028$. And satisfy the consistency check of evaluation matrix and weight calculation. Turn each index data of membership functions and weight distribution and basic credibility of Table 3.

Table 3. Weight and Credibility Distribution

Factors	Indicators	Weight	v_1	v_2	v_3	v_4	v_5
U_1	U_{11}	0.316	0.0569	0.7131	0.1358	0.0947	0.0000
	U_{12}	0.325	0.0000	0.6762	0.1602	0.1213	0.0431
	U_{13}	0.307	0.1429	0.7223	0.0909	0.0252	0.0190
	U_{14}	0.022	0.0000	0.6505	0.1817	0.1205	0.0451
	U_{15}	0.010	0.1993	0.6628	0.0856	0.0523	0.0000
	U_{16}	0.020	0.0860	0.7056	0.1270	0.0652	0.0162
U_2	U_{21}	0.079	0.0366	0.6398	0.2359	0.0867	0.0000
	U_{22}	0.175	0.1745	0.5899	0.1260	0.0658	0.0431
	U_{23}	0.125	0.0000	0.4780	0.3280	0.1165	0.0816
	U_{24}	0.076	0.1250	0.6105	0.1630	0.0621	0.0394
	U_{25}	0.099	0.2035	0.5320	0.1568	0.1077	0.0000
	U_{26}	0.446	0.0000	0.7126	0.0995	0.0762	0.1117

Assumption is sub-layer weight (0.6 0.4), respectively, to guide the index layer, the basic reliability distribution of each element, and synthesis of evidence. Get the credibility of the distribution as shown in Table 4.

Table 4. Synthetic Index Layer After the Credibility of the Distribution

Factors	Healthy Assessment
v_1	0.0910
v_2	0.8089
v_3	0.0627
v_4	0.0147
v_5	0.0120

Solid state transmitter can be obtained 0.7051 of the healthy assessment performance by $E = \sum_{r=1}^{5} P(v_r)m(v_r)$.

In the actual process of radar maintenance, the master of radar factory according to the contents of the "transmitter maintenance manual" solves the problem. Pressure when the waveguide and the healthy status of the standing wave ratio index hours, other parameters of healthy index is higher, at the same time because the transmitter inside and poor day feed impedance matching and make the reflection energy too much, led to too high standing wave ratio and light waveguide, belong to minor failure state. It shows that healthy status evaluation results and the actual results are basically in agreement with the maintenance.

Through data get the fuzzy membership degree of each evaluation index, evaluation index is obtained using membership degree into basic probability distribution of the information provided, and then D-S evidence fusion of evaluation indexes, so as to realize the multilevel and multifactor, scheme of radar transmitter healthy comprehensive evaluation. And through the improvement of D-S resultants, it effectively reduces the conflict between evidence, and improves the credibility of the avionics healthy assessment of PHM.

5. Conclusion

In solid state transmitter, for example, analysis of working principle, from the perspective of healthy status evaluation, will be related to healthy status indicators stratified processing, and then according to the hierarchy correlation index from the bottom of each layer in systems integration, comprehensive consideration of the complexity of the architecture and index measurability, using the analytic hierarchy process . And the D-S evidence fusion is to get solid state transmitter overall healthy assessment results.

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